



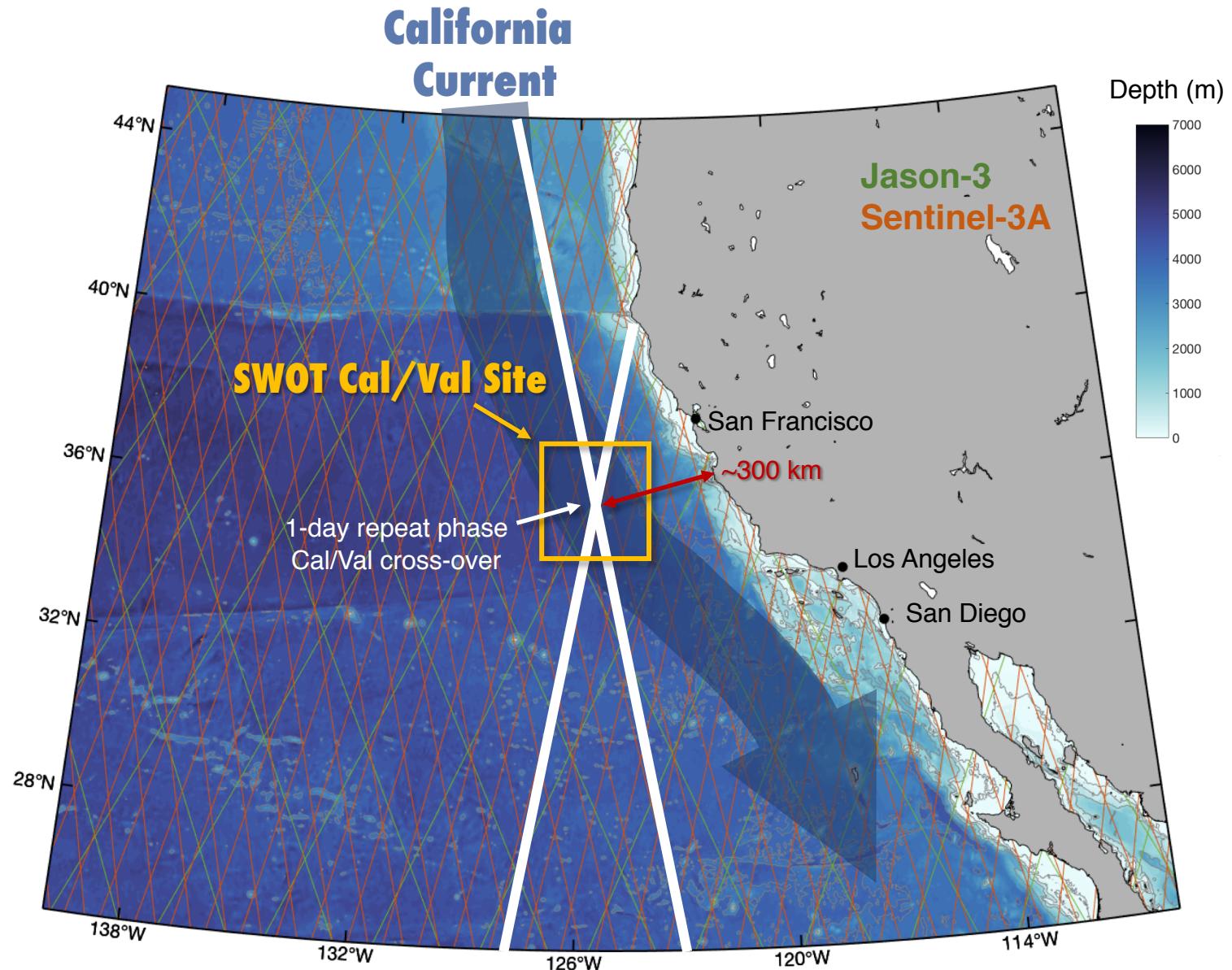
Increasing the Resolution of Mapped Sea Surface Height in the California Current system

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Motivation – SWOT Cal/Val

Pre- and post-launch field campaigns



Motivation – Research Question

- In the California Current system, the **best altimetry product** is SSALTO/DUACS sea surface height (SSH) distributed by **AVISO** (DUACS-DT2018) Le Traon et al. (1998); Pujol et al. (2016)
- However, this is **a global dataset** for a 25+ year period – *not tailored to California Current*
- While along-track SSH resolution is ~65 km, AVISO maps are ~200 km mid-latitude Chelton et al. (2011)
- We know that **regional** studies can provide **improved resolution SSH maps** Pascual et al. (2006); Dussurget et al. (2011); Escudier et al. (2013); Ubelmann et al. (2016)
- There are currently 6 available altimeters for 2019, and potentially 7 for 2021 <http://marine.copernicus.eu>

Q: how far can we push the resolution of SSH maps in the California Current system, using the existing altimetry constellation?

Optimal Interpolation – AVISO

Bretherton et al. (1976), Le Traon et al. (98; 01; 03); Pujol et al. (2016)

Works by minimizing the mean squared error of the solution

$$x = x^b + Wd$$

Weight

R – observational error covariance

Based on:

- Instrument noise (*uncorrelated*)
- Long wavelength error (*correlated*)

Via Gauss-Markov theorem.

“BLUE” *Best Linear Unbiased Estimator*

B – background error covariance

Based on:

- Spatial and temporal correlation scales
- Propagation speeds

$$W = BH^T(HBH^T + R)^{-1}$$

Background error covariance
between grid point and observation point

Background error covariance **between observation points**

optimized for the global ocean and
25+ years with variable altimetry coverage

Our Methodology – 2-D Variational Analysis (2DVAR)

[Chao et al. \(2009\); Li et al. \(2016\)](#)

Solves for least squares solution via a different approach – by minimizing a cost function:

$$J(x) = \underbrace{\frac{1}{2}(x - x^b)^T B^{-1}(x - x^b)}_{\text{Background}} + \underbrace{\frac{1}{2}(y^o - Hx)^T (R + F)^{-1}(y^o - Hx)}_{\text{Observations}}$$

‘Increment’

‘Innovation’

Background

Observations

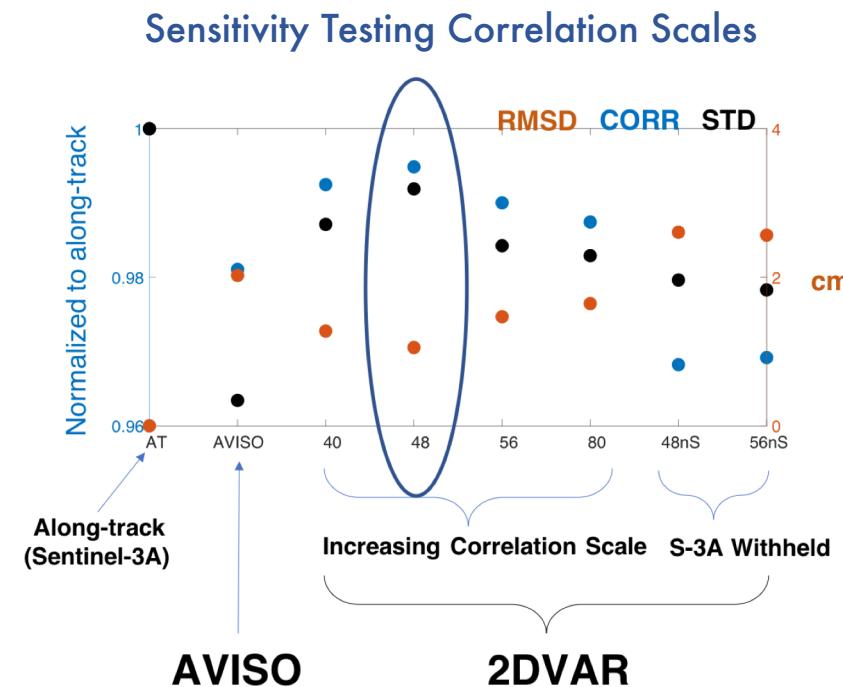
Advantages for implementation:

- Computationally faster – optimization method
- Uses all available data – no need to sub-sample, and additional data can be added without increased computation time
- More flexible to add additional constraints (future work), anisotropic error covariances

2-D Variational Analysis (2DVAR)

Key modifications in our approach compared with AVISO*

1. Smaller correlation scale
2. Background field – prior day's full-resolution field
3. No smoothing of along-track data
4. No time correlation function
5. Addition of a *representation* error in R, to penalize observations further away in time



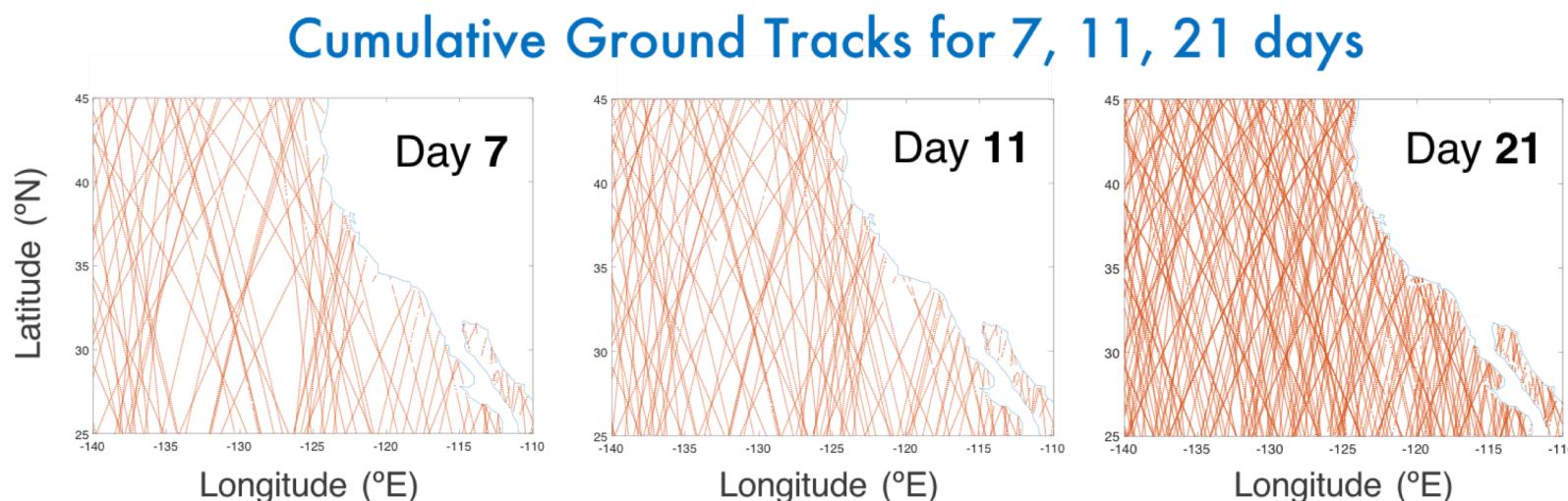
Dataset

DUACS-DT2018 (L3) unfiltered along-track altimetry data

Publicly available through the Copernicus website
<http://marine.copernicus.eu/>

Between **Jan to June 2018** there were **5** altimeters in orbit:

- 1. Jason-3
 - 2. Sentinel-3A
 - 3. SARAL/AltiKa-DP
 - 4. Cryosat-2
 - 5. HaiYang-2A G
- } REPEAT
} GEODETIC



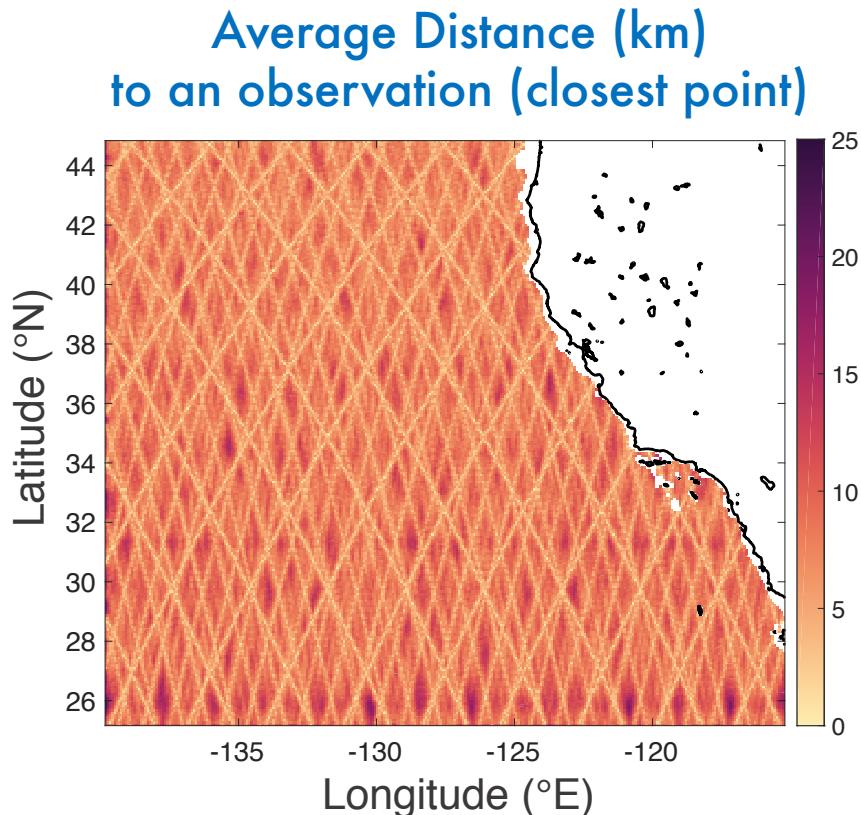
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DUACS-DT2018 (L3) unfiltered along-track altimetry data

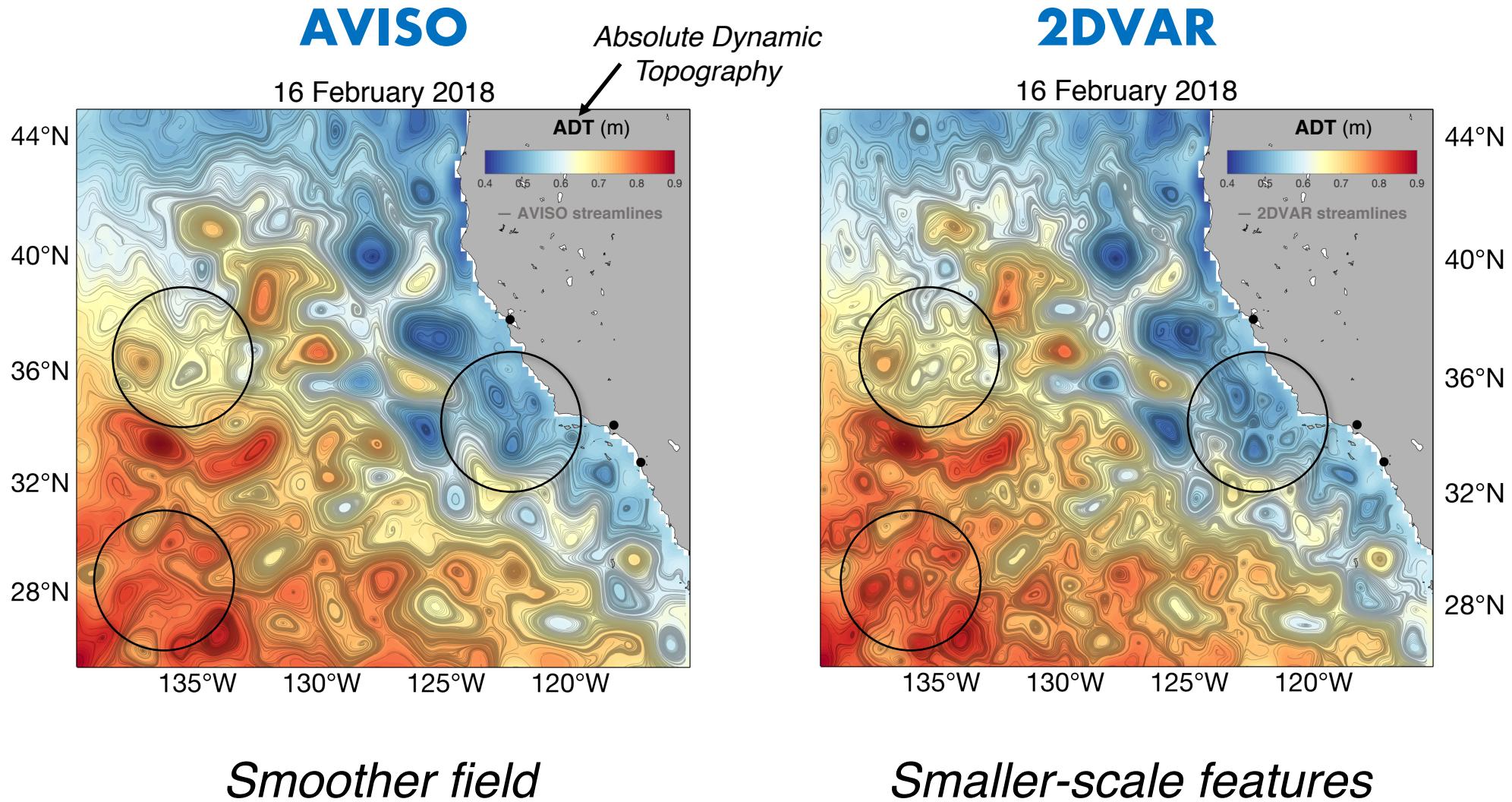
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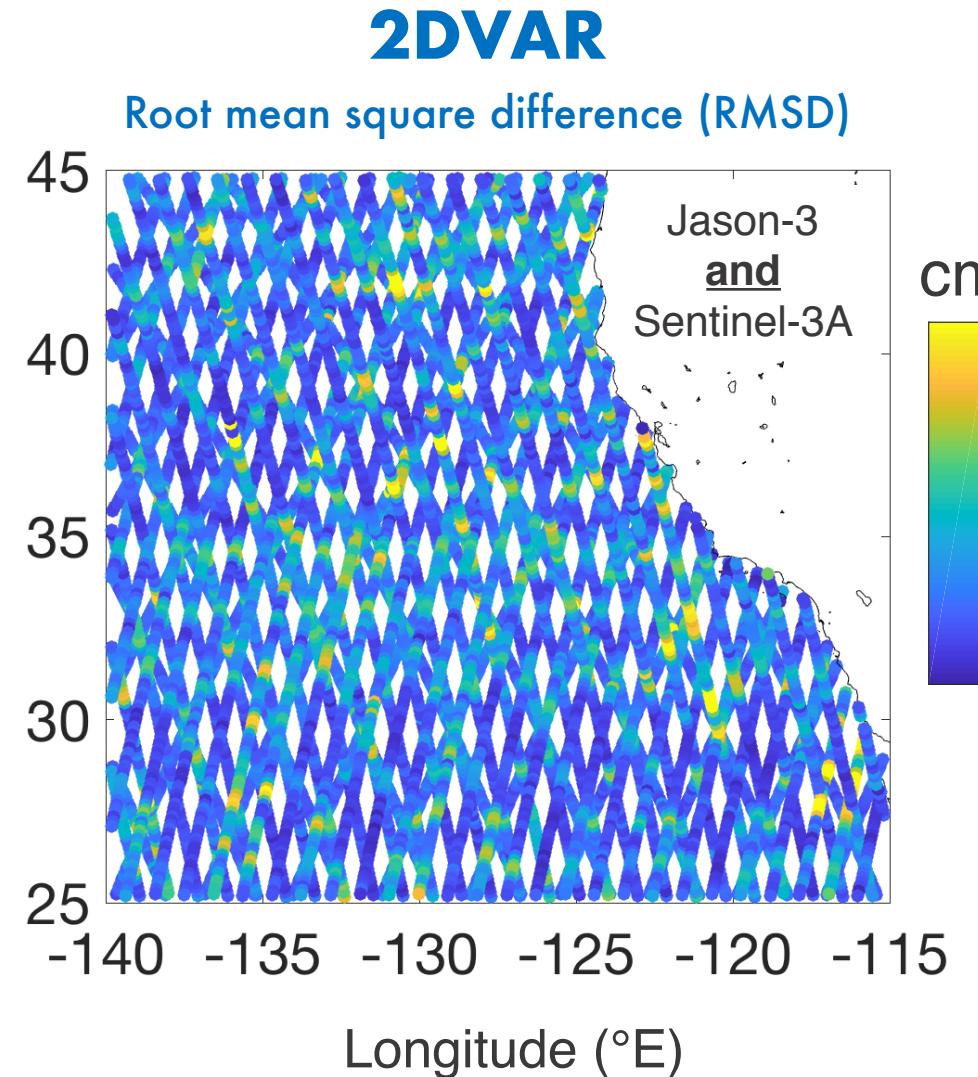
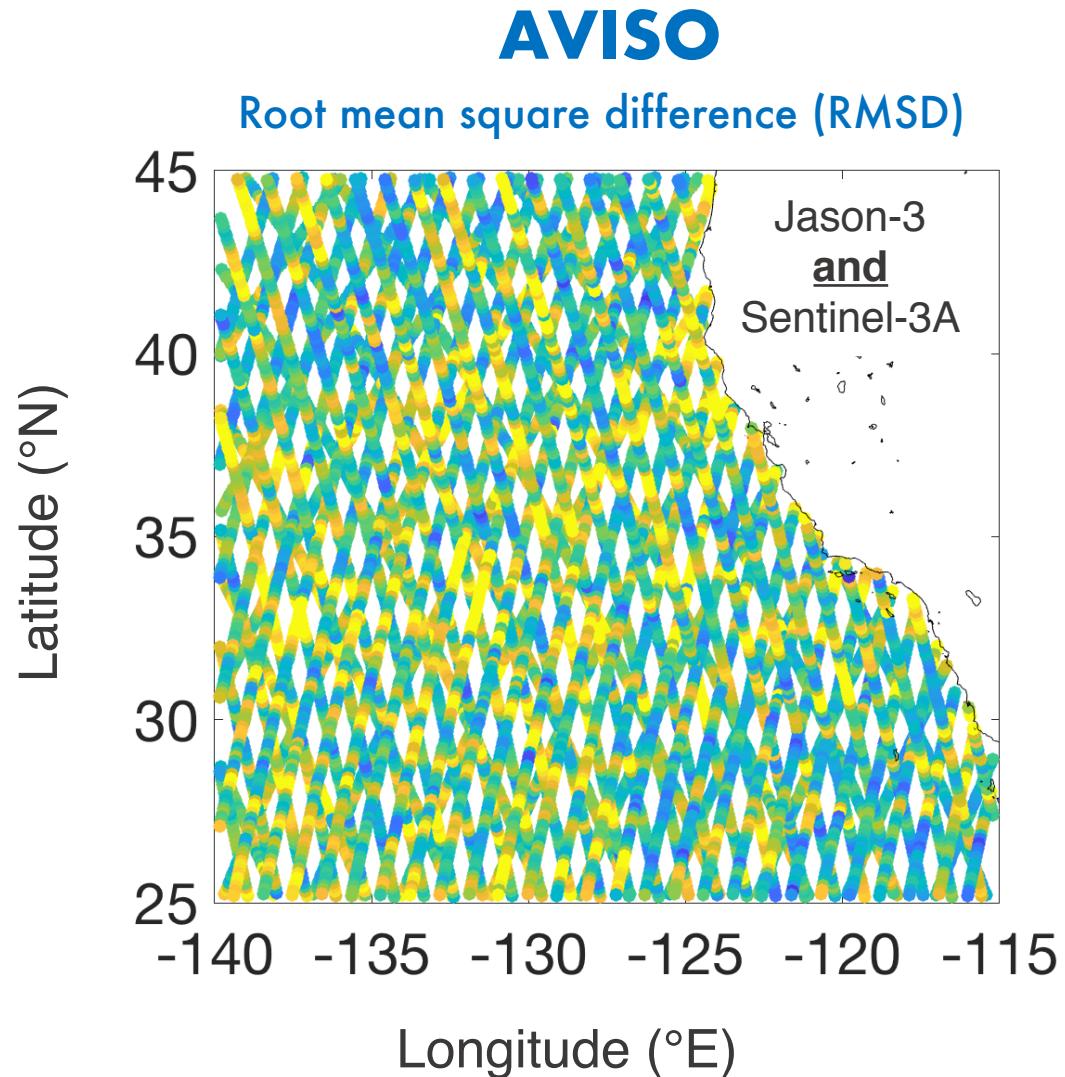
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Results – A Snapshot View



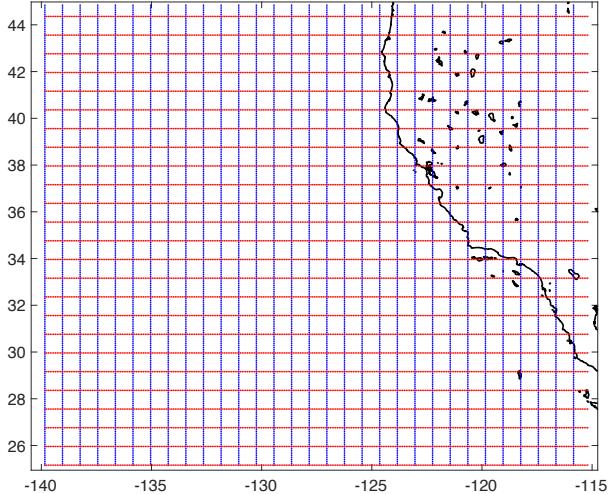
Results – Mapping Performance vs. Along-Track (included)



Results – SSH Wavenumber Spectra

How does the variability match up over different spatial scales?

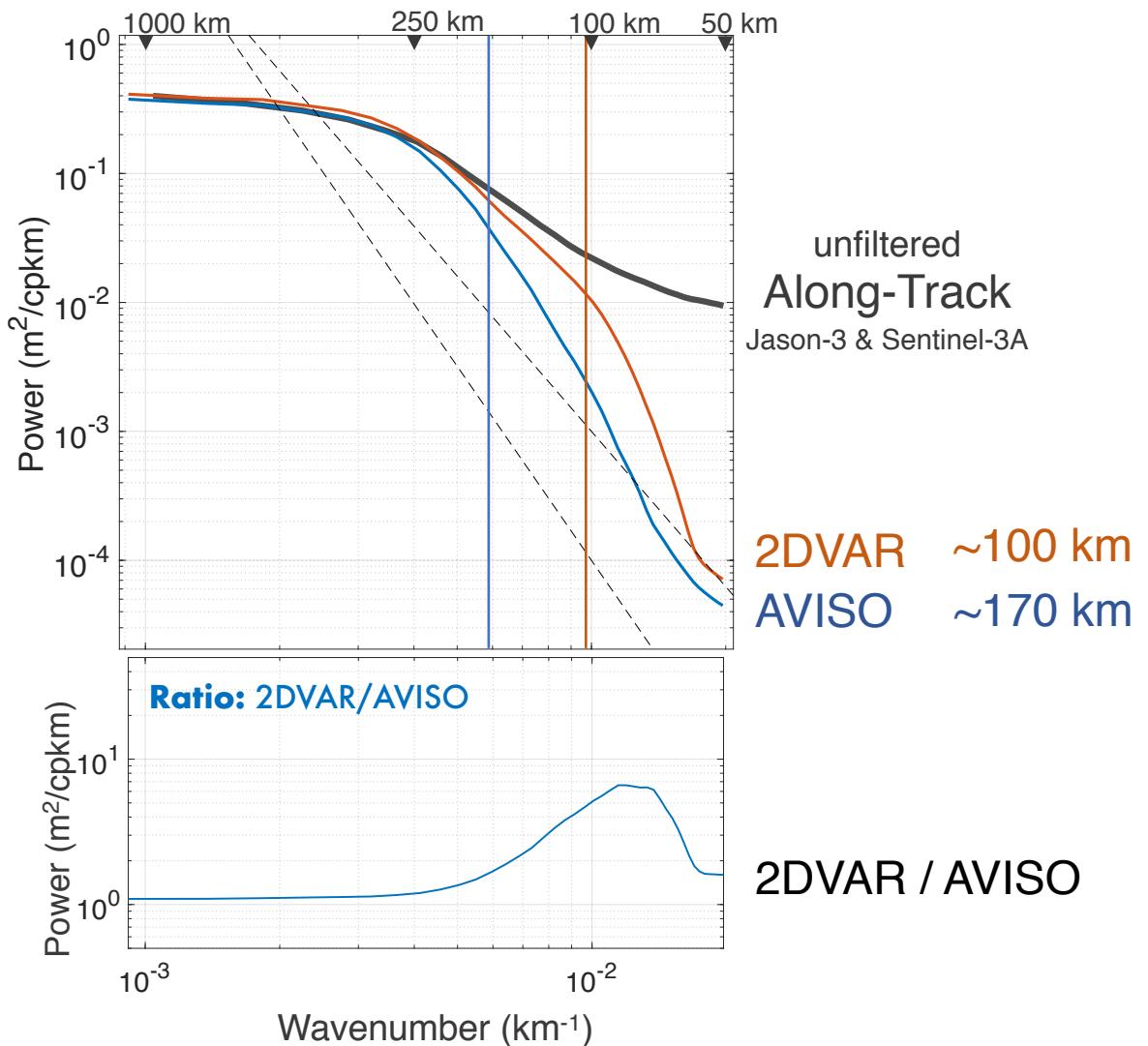
Zonal and Meridional Transects



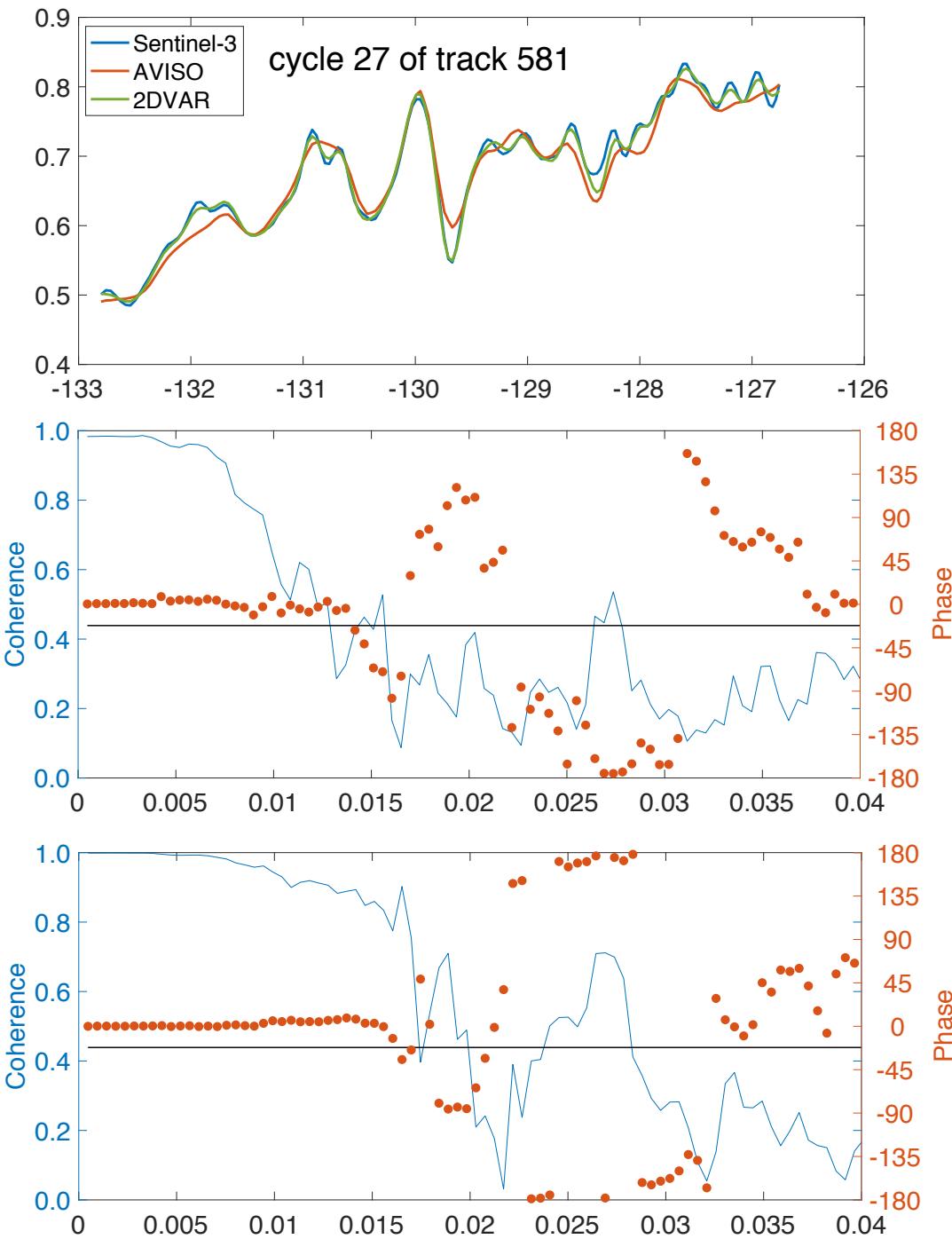
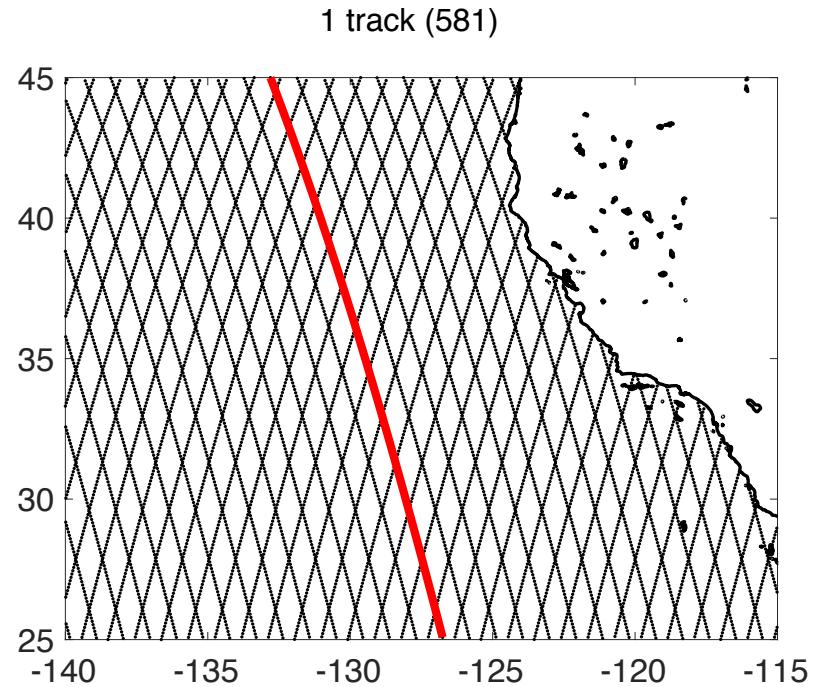
EFFECTIVE RESOLUTION

Defined as wavenumber where power spectral density of map is **half** of along-track [Chelton and Schlax. \(2003\)](#)

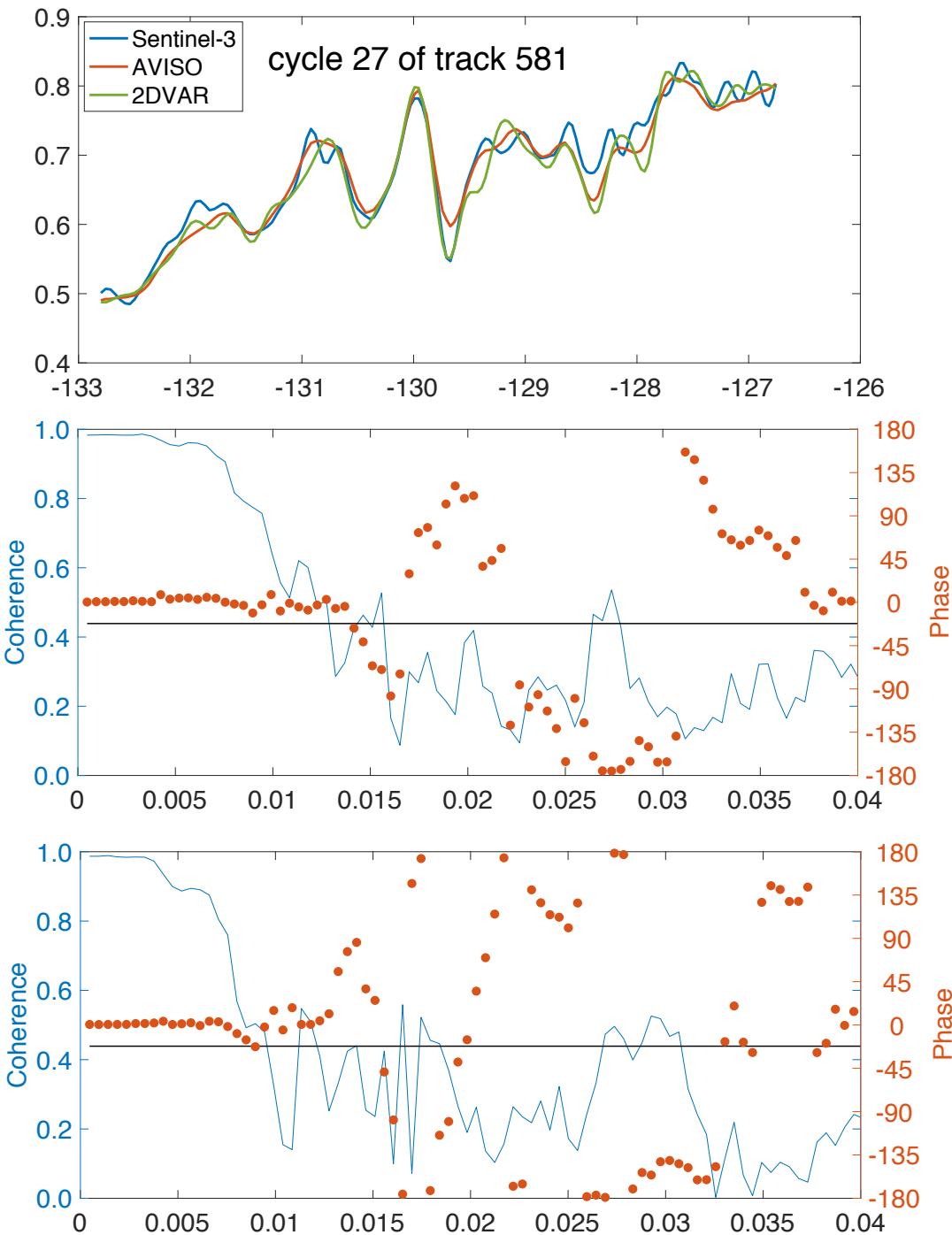
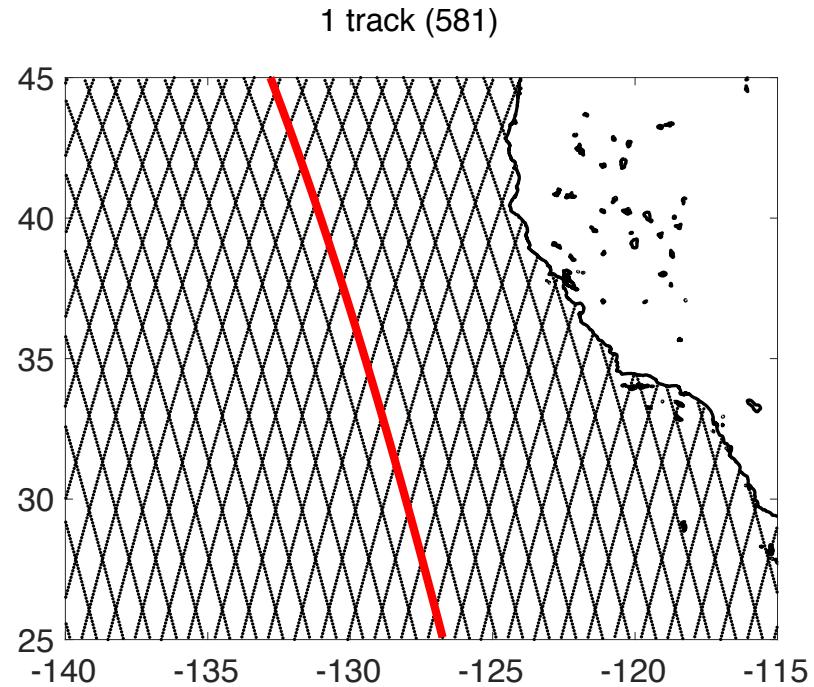
Mean 1-D Wavenumber Spectra



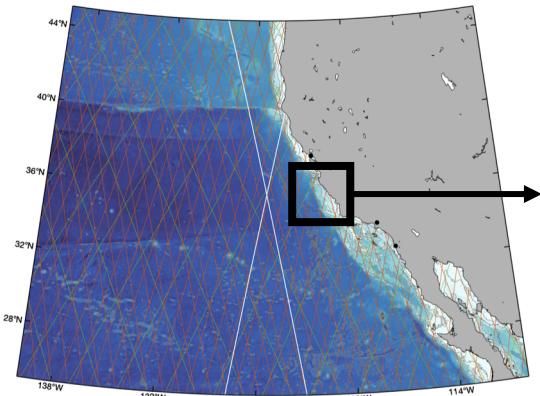
Results – Coherence



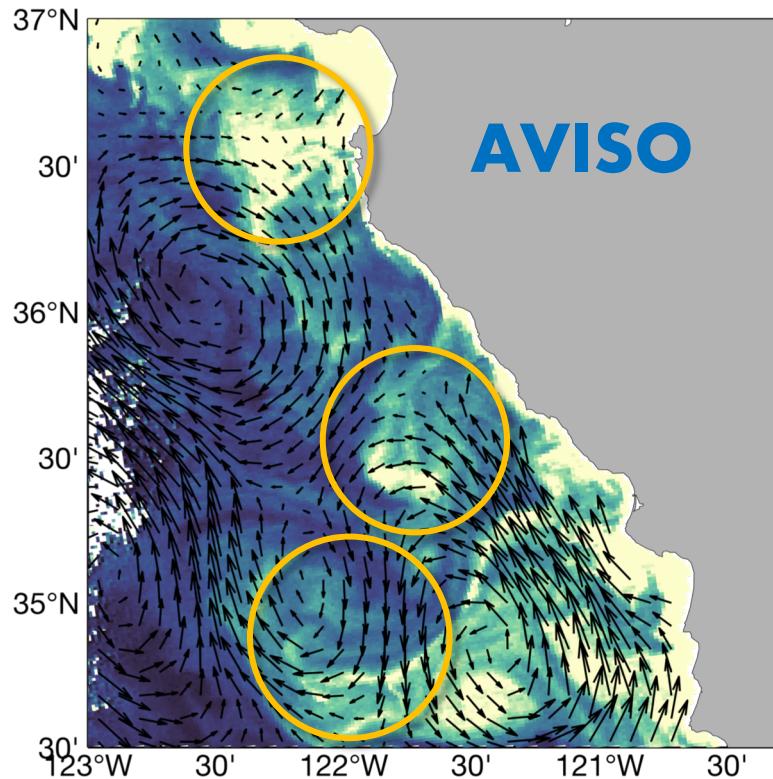
Results – Coherence (withheld)



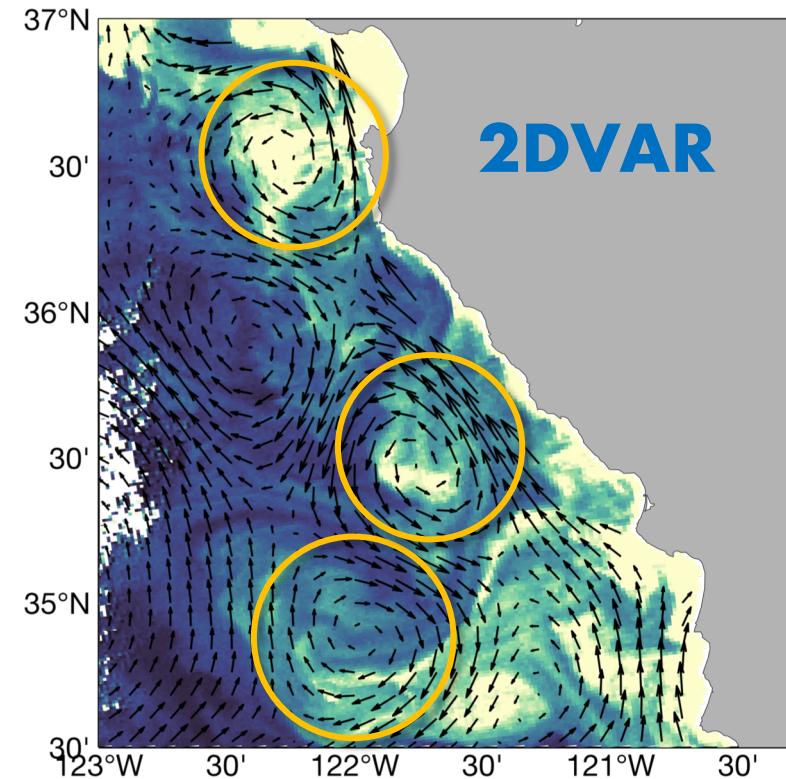
Independent Data – Satellite Imagery



AVISO misses coastal features



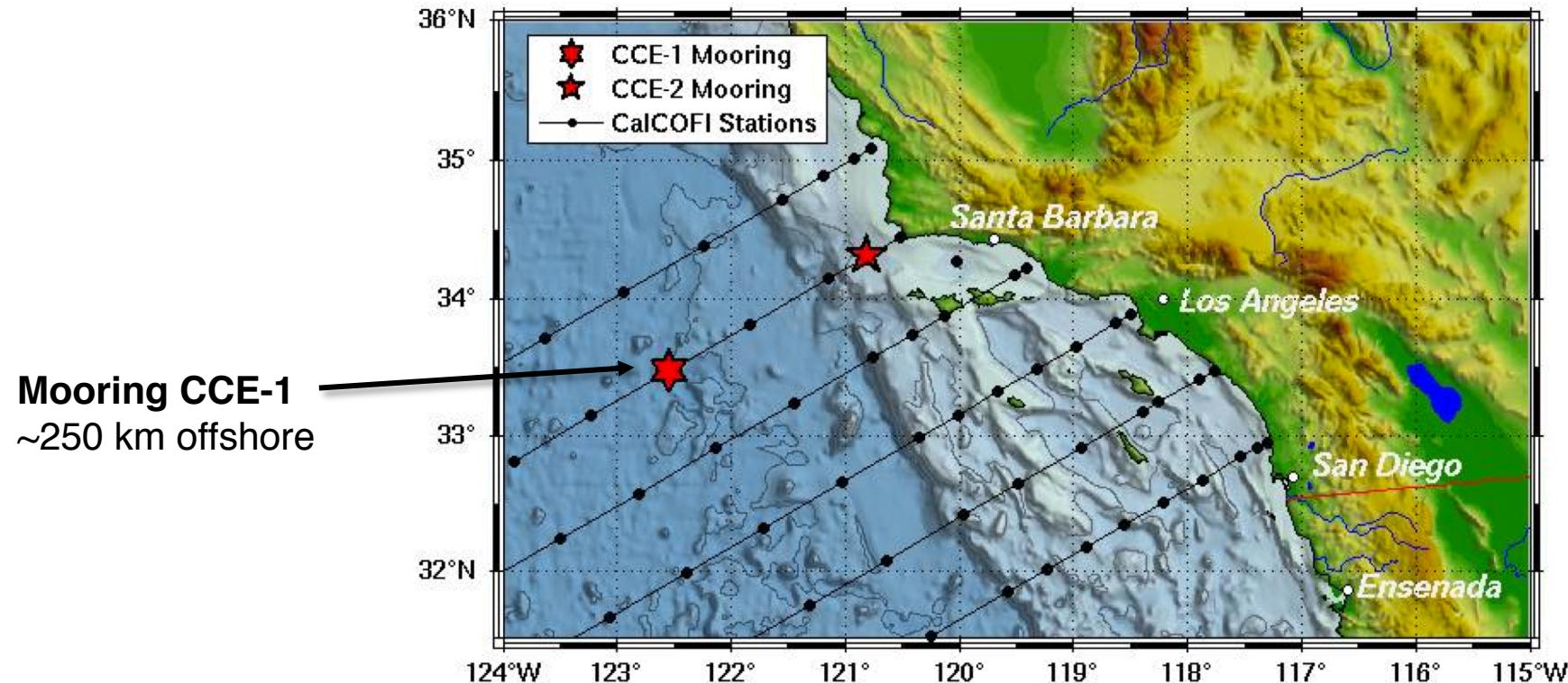
2DVAR picks up smaller-scale eddies



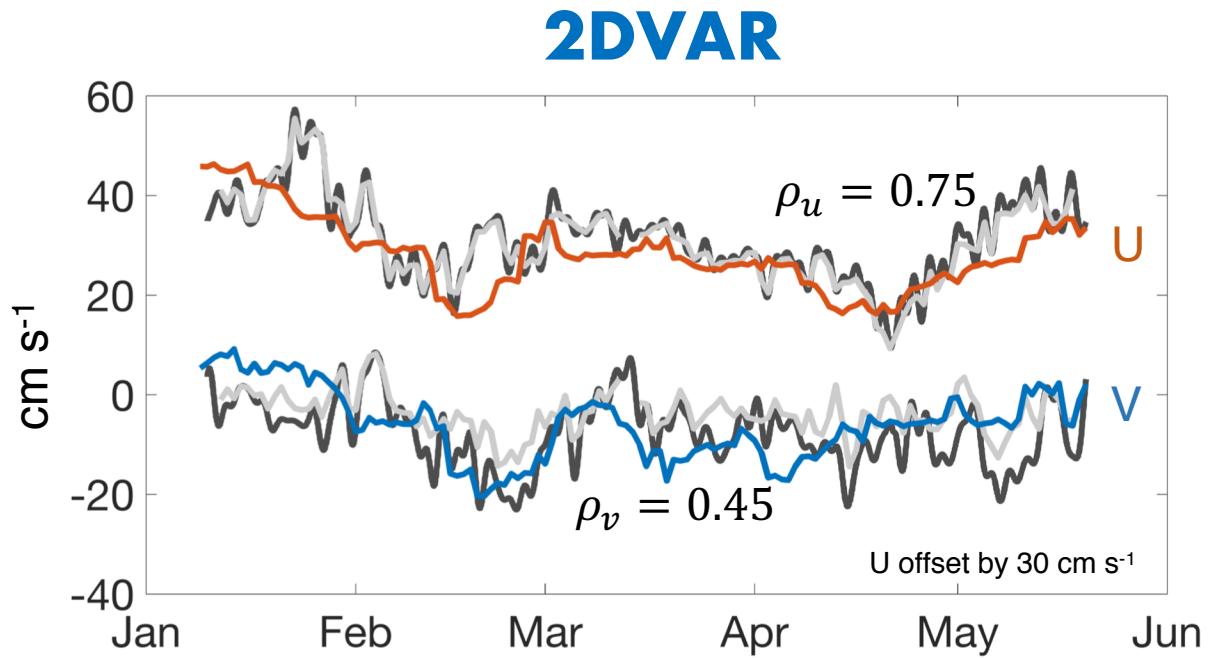
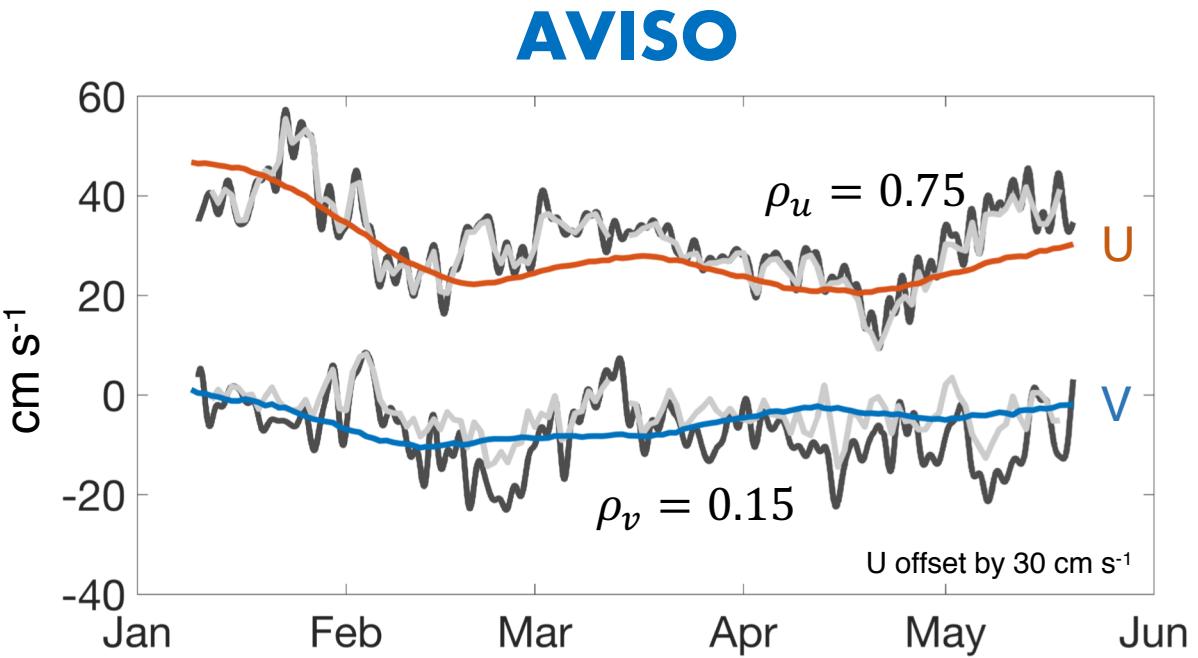
Independent Data – In situ ADCP velocity

“California Current Ecosystem” CCE Project, Interdisciplinary Biogeochemical Moorings

Investigators: U. Send, M. Ohman, D. Demer, T. Martz, C. Sabine, J. Hildebrand, A. Dickson

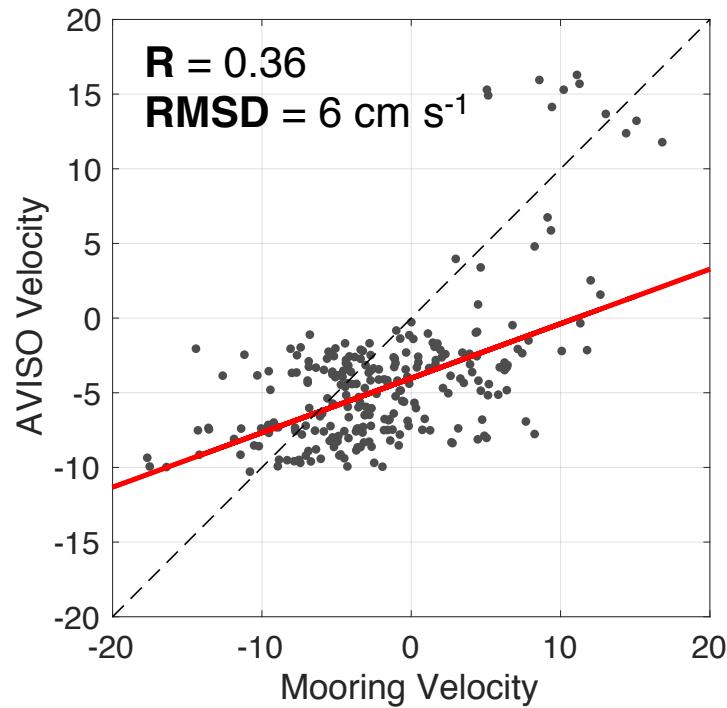


Independent Data – In situ ADCP velocity

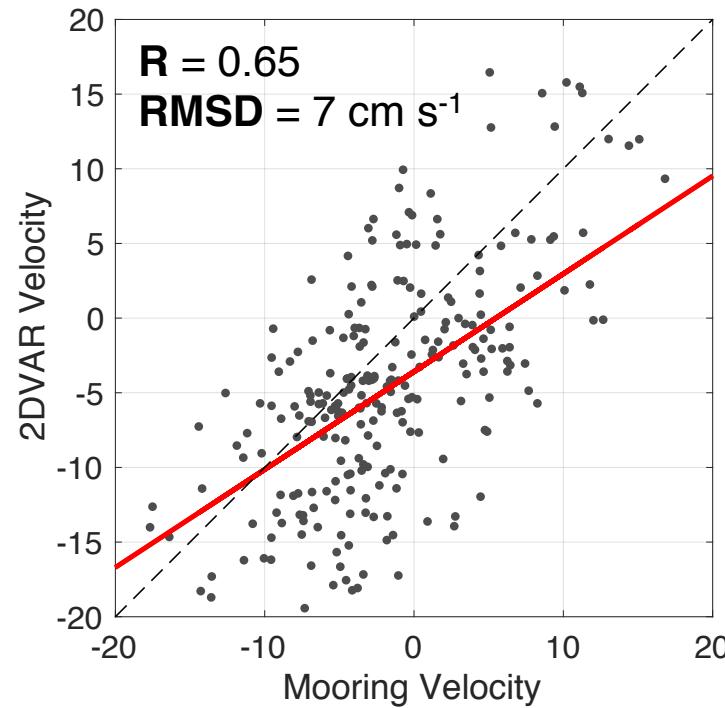


Independent Data – In situ ADCP velocity

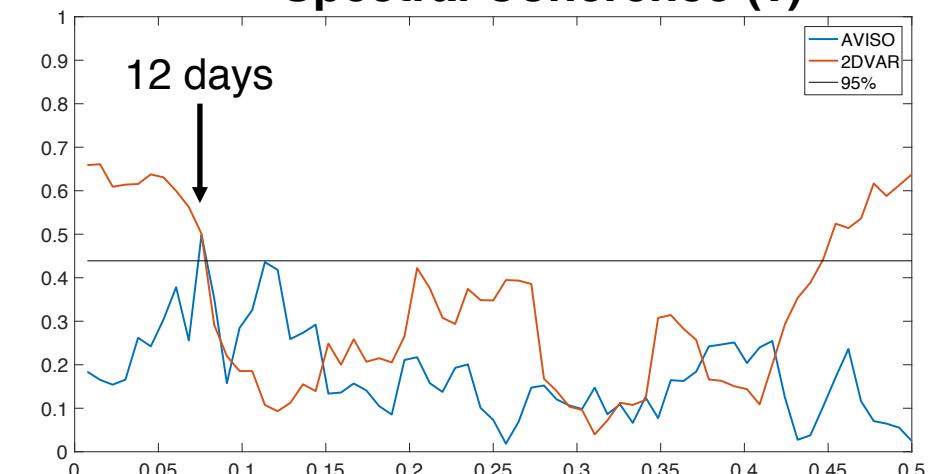
AVISO



2DVAR



Spectral Coherence (ν)



Summary

- Jan-June 2018 there were **5** altimeters in orbit, in 2019 there are **6**, in 2021 – **7**?
- Goal: use this large number of altimeters to see **how far we can push the resolution of SSH maps in space and time** in the California Current system
- We apply a variational method to map along-track measurements
 - **equivalent solution** to optimal interpolation, but *different approach*
 - more computationally efficient and flexible to refine
- Preliminary focus: correlation scales, background field, and time representation (resolution > uniform error)
- Obtain **finer scale maps than AVISO (100 km vs. 170 km)**
 - probably a combination of signal and noise

Ongoing Work

- **Further testing:**
 - More comprehensive withheld along-track comparison – longer time period
 - More independent dataset analysis – drifters, HF radar
 - Dynamical test – how well does each dataset follow quasi-geostrophy? (PV conservation)
 - Perhaps explore method and data using a data assimilating model
- **Improve and enhance the method:**
 - Improve the time representation error (F)
 - Incorporate long wavelength error, and refine the uncorrelated error budget
 - Consider constraints (dynamical ([Ubelmann et al., 2016](#)), topography ([Escudier et al., 2013](#)), etc.)

Thank You!